

# Western Australian Museum Meteorite Collection

by Aubrey Whymark

Images from 2008, prepared 2017.




## WEATHERED STONY METEORITES

### RECOGNISING GENUINE METEORITES

Meteorites come in all shapes and sizes and are made of diverse materials. Meteorites are usually recognised because they look very different from most rocks. Freshly fallen stony meteorites are coated with matt or shiny black fusion crusts. The crust, is usually only about 1 millimetre thick and where the crust has broken away the fresh interior can often be seen. Most meteorites contain some metallic iron and will attract a compass needle. In many stony meteorites, metal shows up on their surfaces as abundant silvery specks. Meteoritic metal always contains nickel and usually contains very little carbon. This allows it to be easily distinguished from industrial cast-iron, which lacks nickel and is made up mainly of iron and carbon. Commercial steel can contain nickel, but may also contain substantial amounts of manganese, chromium and tungsten which meteoritic metal does not. Ultimately, the identification of a meteorite requires expert examination.

## METEORITES



## NATURALLY OCCURRING NODULES AND CONCRETIONS



## WEATHERED SANDSTONE



CUT SLICE OF STONY METEORITE

FRESH STONY METEORITES



CUT SLICE OF STONY METEORITE

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WEATHERED STONY METEORITES

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**METEORITES**

NATURALLY OCCURRING IRON OXIDE CONCRETIONS

WEATHERED SANDSTONE

#### PYRITE NODULES

These nodules commonly form in a variety of sedimentary rocks such as shales, limestone and coal. Pyrite (iron disulphide) is a common mineral. When broken open they usually reveal brassy yellow radiating crystals, but surfaces weather to brown or black.

#### METEORWRONGS PSEUDOMETEORITES

There are many objects that are commonly mistaken for meteorites. Natural 'pseudo-meteorites' include rounded nodules of ironstone. These form by deposition of iron oxides from mineralised fluids seeping through sedimentary rocks. Often harder than their surroundings, concretions frequently survive long after the rocks in which they formed have completely eroded away. Other 'pseudo-meteorites' are near-spherical nodules of the mineral pyrite that also form in sedimentary rocks. Weathered pyrite nodules have brown crusts of iron-oxides, but on freshly broken surfaces they have long, radiating brassy yellow crystals. 'Meteorwrongs' also include a variety of rocks, and the man-made products and wastes ('slags') from industry. The latter include cast-iron, glass and silicates. Furnace wastes often contain bubbles that formed as the result of the expulsion of gas during melting. In contrast, with few exceptions, meteorites almost never contain large gas bubbles.

### METEORWRONGS

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METEORWRONGS

WEATHERED SHALE BALL

HENRIEY

WEATHERED IRON METEORITES

THUNDA

WEATHERED STONY-IRON

SLICES OF IRON METEORITES TREATED WITH ACID TO SHOW THEIR INTERNAL STRUCTURES

FRESH STONY-IRON

POURED

CAST-INDU SLAG

METEORITES



CHROMIUM STEEL FROM A BOMB CASING  
*Found near ...*

MILD STEEL  
*Found near ...*

GLASSY INDUSTRIAL SLAG

CAST IRON  
*Found near ...*

CAST IRON BALL FROM A BALL MILL  
*Near Horse Shoe Lights*

INDUSTRIAL SLAG FROM A COPPER SMELTER  
*Near Ravenshorpe*

POURED LEAD

FERRO SILICON

CAST-IRON, STEELS AND INDUSTRIAL WASTES SLAGS

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METEORWRONGS





WEATHERED SHALE BALL  
Well Creek

CHROMIUM STEEL FROM  
A BOMB CASING  
Found near Brisbane

HENBURG

WEATHERED IRON METEORITES

CAST IRON  
Found near Esperance

THUNDA

WEATHERED STONY-IRON

INDUSTRIAL WASTE  
Found near Bowen

FERRO SILICON

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TREATED WITH ACID TO SHOW  
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FRESH STONY-IRON

CAST-IRON, STEELS AND  
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METEORWRONGS



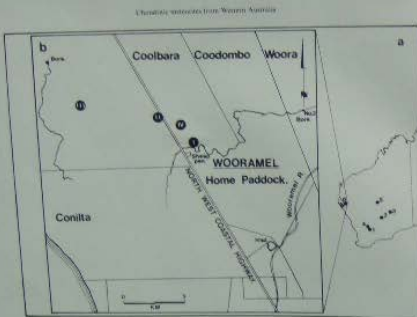


Figure 1a. Locations of discovery of the Baandee (1), Jeedamya (2), Mount Margaret (3), Nimberrin (4), Millrose (5) and Wooramel (6) meteorites from Western Australia.

1b. Enlargement of the area surrounding Wooramel Station (a) showing the distribution of the four known masses of the Wooramel meteorite shower.

The meteorite (Figure 2a) has a flatly domed, elongated shape and clearly remained orientated during atmospheric passage. The posterior surface is flat and coated with thick (c. 0.5 mm), stepped fusion crust. The anterior surface is generally convex, curves sharply towards the posterior surface and is decorated with radial flow lines. One end of the stone is truncated by a scalloped surface from which a fragment may have become detached during atmospheric flight.

On cut surfaces, the meteorite displays conspicuous chondrules up to 2 mm in diameter and abundant, fresh particles of metal set in a faintly iron-stained, fibrous crystalline silicate matrix.

**Wooramel.** In April 1969, Mr. R. A. Hall, the owner of Wooramel Station (sq. v. 1) (25° 44' S, 114° 17' E), found a large noisy meteorite close to the Station's sheep pens (29° 39' S, 114° 17' E). The pens are approximately 10 km NW of Wooramel Homestead, on the eastern side of the North West Coastal Highway (Figure 1b). The meteorite (WAM 13016), weighing 45 kg, was buried to a depth of 3 cm in red, loamy soil.



Figure 2. The Baandee (a), Jeedamya (b), Mount Margaret (c), Nimberrin (d), and Millrose (e) meteorites, and (f) the main mass (no. 1) of the Wooramel meteorite shower.

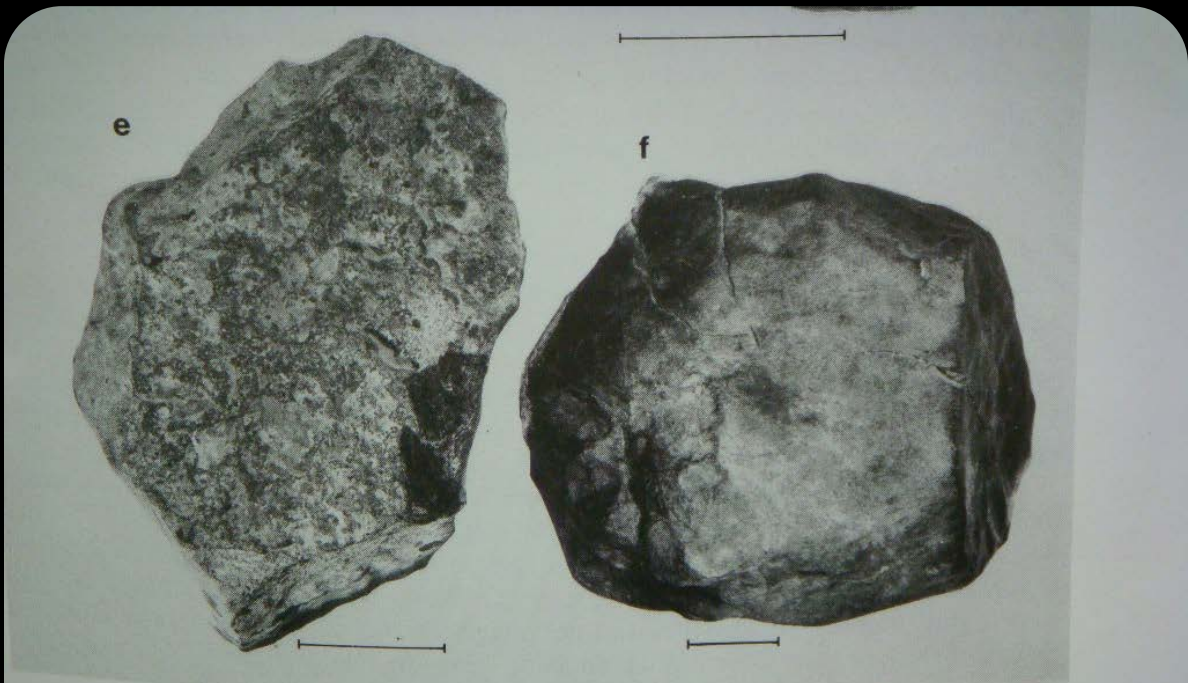
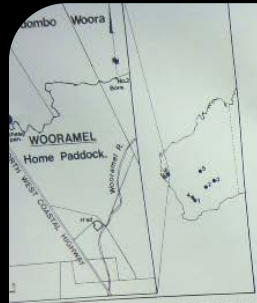


Figure 2. The Baandee (a), Jeedamya (b), Mount Margaret (c), Nimberrin (d), and Millrose (e) meteorites, and (f) the main mass (no. 1) of the Wooramel meteorite shower.



Wooramel (1), Jeddahya (2), Mount Margaret (3), Nimberrin (4), and Millrose (5) meteorites from Western Australia.

Figure 1. Surrounding Wooramel Station (a) showing the distribution of the Wooramel meteorite shower.

The meteorite has a flatly domed, elongated shape and clearly remained in its original position. The posterior surface is flat and coated with a thin layer of soil. The anterior surface is generally convex, curves upwards and is decorated with radial flow lines. One end of the meteorite is rounded and appears to have become fused to the ground.

The meteorite displays conspicuous chondrules up to 2 mm in diameter and contains small particles of metal set in a faintly iron-stained, friable matrix.

Mrs. R.A. Hall, the owner of Wooramel Station (a) (25° 30' S, 115° 15' E) reports that she discovered the meteorite close to the Station's sheep pens (25° 30' S, 115° 15' E) on 10 km NW of Wooramel Homestead, on the West Coastal Highway (Figure 1b). The meteorite (WAM 195/18.1) was buried to a depth of 3 cm in red, loamy soil.

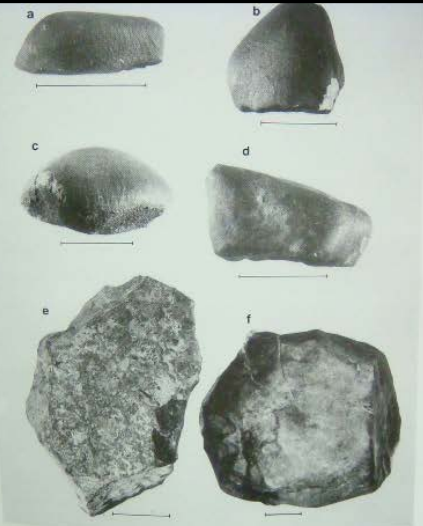


Figure 2. The Brander (a), Jeddahya (b), Mount Margaret (c), Nimberrin (d), and Millrose (e) meteorites, and (f) the main mass (in 1) of the Wooramel meteorite shower.



### Haig meteorite

Nullarbor, Western Australia

Group IIIAB iron

A mass of 450 kilograms found in 1951 in the Nullarbor south of Rawlinna on the Trans Australian Railway. Presented by the finders, A. J. and H. E. Carlisle. The thumb print like depressions on the surface of the meteorite, called regmaglypts, resulted from turbulent airflow and uneven melting when it passed through the atmosphere.



Edith meteorite  
Nullarbor, Western Australia  
Group IIIAB iron  
A large mass found in the Nullarbor south of Rawlinna on the Trans Australian Railway. Presented by the finders, A. J. and H. E. Carlisle. The thumb print like depressions on the surface of the meteorite, called regmaglypts, resulted from turbulent airflow and uneven melting when it passed through the atmosphere.

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### Mount Edith meteorite

Western Australia

Group IIIAB iron

The second of two large masses found in the Ashburton district in 1913-14. This larger mass weighed 165.1 kilograms when it was found by James Bourke in 1914.



### Mount Dooling meteorite

North Yilgarn, Western Australia

First found in 1909

Group IC iron meteorite

This mass of 701 kg is the largest of four meteorite masses attributed to the same ancient meteorite fall, the first of which was found in 1909. This meteorite was found by Joshua Pitt and Alan Pellegrini near the Mount Manning Range in 1979. The delta-wing shape and smooth underside resulted from uniform flight through the atmosphere.





**Iron meteorite**  
Australia

Four meteorite masses were the first of which were found by Arthur W. Elphinstone in 1866. The meteorite masses resulted from

Iron meteorite  
Australia



**Mount Dooling meteorite**  
North Pilbara, Western Australia  
First found in 1907  
Group IC iron meteorite

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Iron meteorite  
Australia

Iron meteorite  
Australia





**Youanmi meteorite**  
Western Australia  
Group IIIAB iron  
A mass of 118.5 kilograms was found in 1917  
about 80 kilometres south of Youanmi.

# ROCKS FROM THE MOON AND MARS

Since 1969 we have gained much detailed information about the Moon from rocks returned to Earth by manned Apollo space missions launched by the United States National Aeronautics and Space Administration (NASA) Space program. In addition, thirteen meteorites found in Antarctica, one found in Western Australia and two from the Sahara in Algeria are also known to have come from the Moon because they are like rocks collected by the Apollo space missions. The importance of lunar meteorites is that they come from areas of the Moon not sampled by manned missions. Another fourteen meteorite specimens are known to be pieces of the planet Mars.



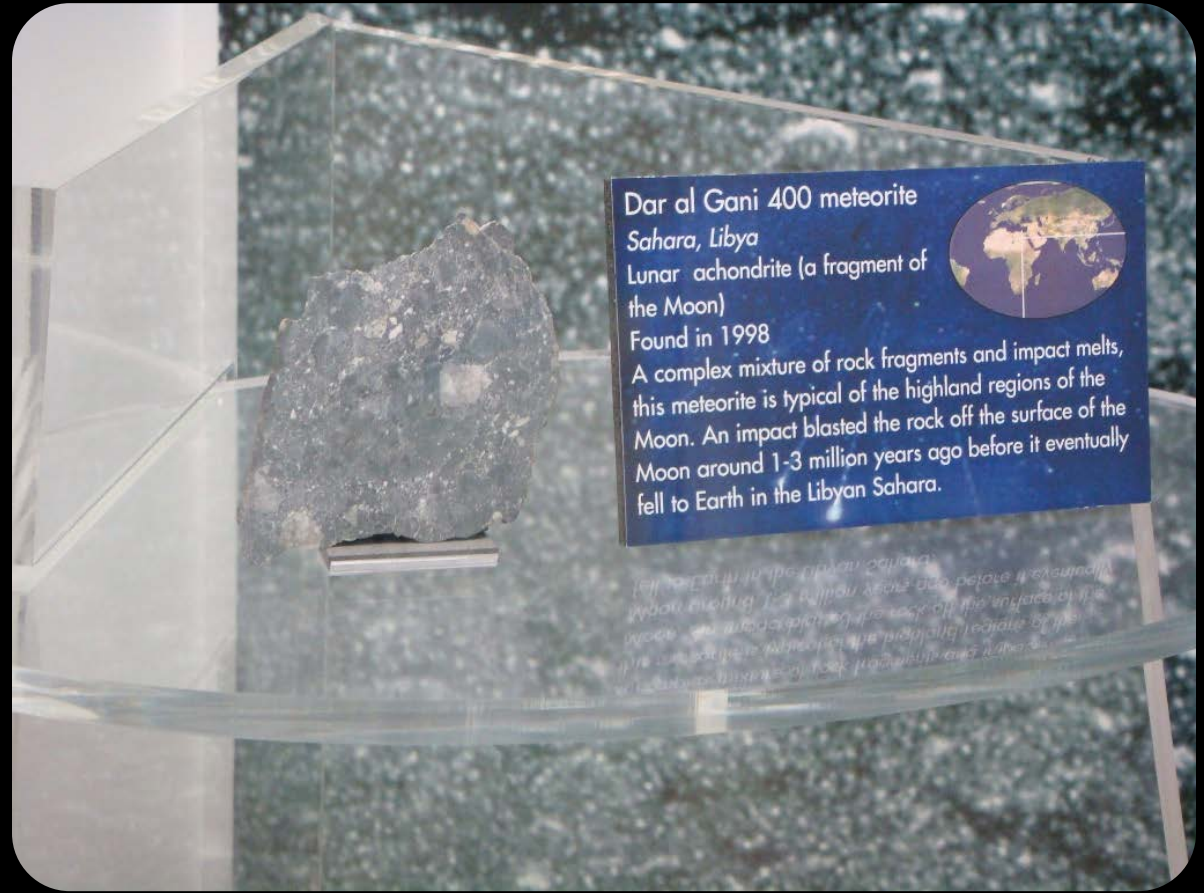
**One of the 200 meteorites**  
 from the Sahara in Algeria  
 is known to have come from the Moon because they are like rocks collected by the Apollo space missions.

**THE MOON**  
 The only natural satellite of Earth, the Moon was the first celestial body to be visited by humans. It is the only celestial body in the Solar System that is visible to the naked eye from Earth. The Moon is the only celestial body in the Solar System that is visible to the naked eye from Earth.

**Mars meteorites**  
 are rocks that have been ejected from the surface of Mars and have landed on Earth. They are the only rocks from another planet to be found on Earth.

**Apollo 16 meteorites**  
 are rocks that were collected by the Apollo 16 mission in 1968. They are the only rocks from the Moon to be found on Earth.

**ROCKS FROM MARS**  
 are rocks that have been ejected from the surface of Mars and have landed on Earth. They are the only rocks from another planet to be found on Earth.



**Dar al Gani 400 meteorite**  
 Sahara, Libya  
 Lunar achondrite (a fragment of the Moon)  
 Found in 1998  
 A complex mixture of rock fragments and impact melts, this meteorite is typical of the highland regions of the Moon. An impact blasted the rock off the surface of the Moon around 1-3 million years ago before it eventually fell to Earth in the Libyan Sahara.

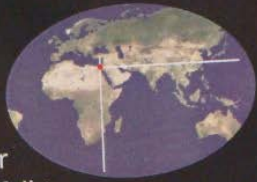


### Nakhla meteorite

Egypt

Martian achondrite

Fragment from a shower of stony meteorites that fell in 1911, one of which is reported to have killed a dog. This igneous rock from Mars, which formed 1 300 million years ago, is much younger than most other meteorites (4 560 million years) and so must have come from a large parent planet with active volcanoes at that time.



### Zagami meteorite

Nigeria


Martian achondrite

A slice of the meteorite originally weighing 88 kilograms that fell on 3 October, 1962. Like Nakhla it has proved to be from Mars. NASA's Mars missions have included the two Viking unmanned probes that were launched in 1975 and 1976. The probes analysed soil and atmosphere samples and relayed the results to Earth. The composition of the Martian atmosphere is a close match for the gases contained in these meteorites and provide part of the proof that they came from Mars.






**Dar al Gani 476 meteorite**  
Sahara, Libya  
Martian achondrite  
Found in 1998  
Many meteorites that probably  
came from Mars are now being found preserved in  
the world's deserts.

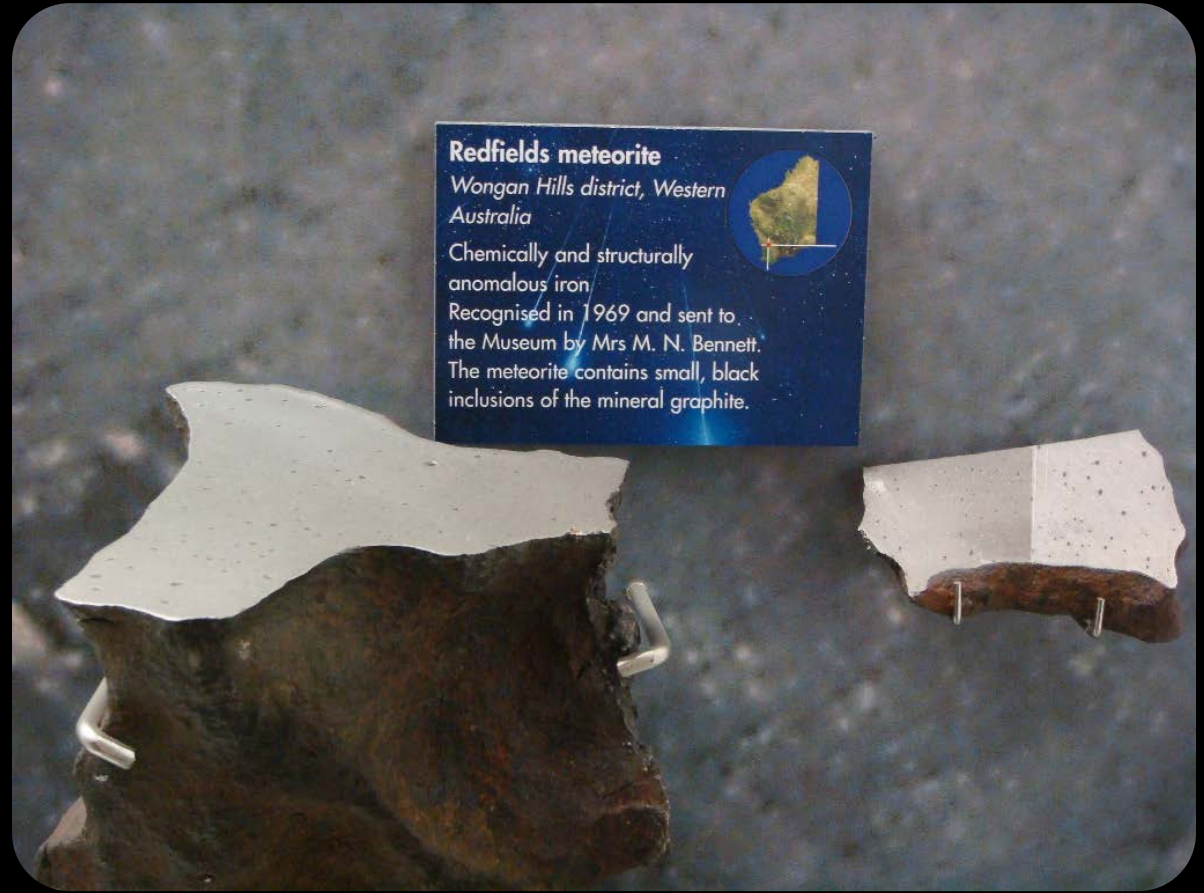


**Redfields meteorite**  
Wongan Hills district, Western  
Australia  
Chemically and structurally  
anomalous iron  
Recognised in 1969 and sent to  
the Museum by Mrs M. N. Bennett.  
The meteorite contains small, black  
inclusions of the mineral graphite.





**Gundaring meteorite**  
Western Australia  
Group IIIAB iron  
Found by F. Quinn  
in 1937.

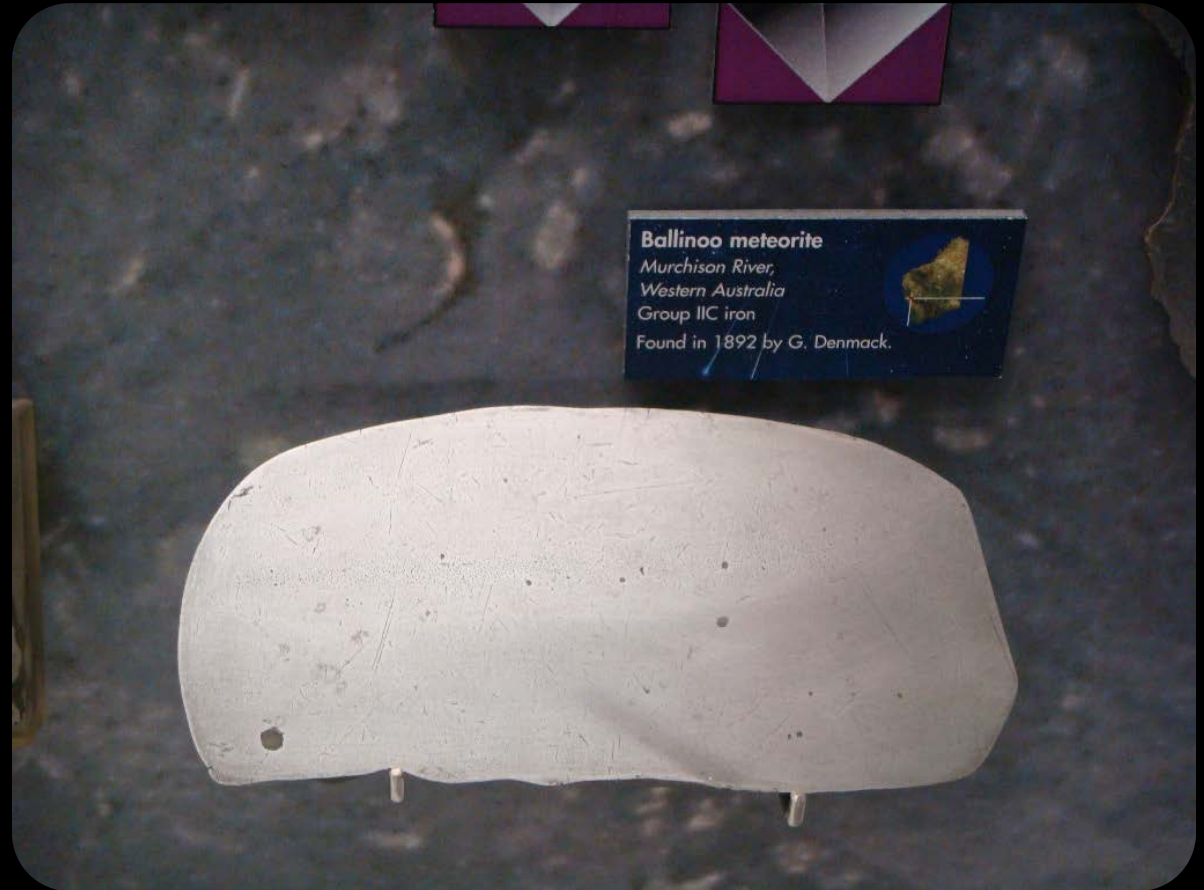



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**Portales Valley meteorite**  
Roosevelt County, New Mexico, USA  
H-group ordinary chondrite (H6)  
Fell on 13 June, 1998 at 7:30 am  
local time. This meteorite is an unusual  
mixture of rock and large veins of metal probably  
produced by catastrophic collisions in space.



**Ballinoo meteorite**  
Murchison River,  
Western Australia  
Group IIC iron  
Found in 1892 by G. Denmack.



**Woodbine meteorite**

Jo Davies County,  
Illinois, USA  
Group IAB  
anomalous iron  
Found in 1953.  
Some irons like Woodbine contain  
inclusions of silicate.



**Sardis meteorite**

Burke County,  
Georgia, USA  
Group IAB iron  
Found in 1940.  
This meteorite is made  
of coarse interlocking  
iron-nickel mineral  
bands of the mineral ta

**North Chile  
meteorite**

Antofagasta, Chile  
Group IIAB iron  
Found in 1875.  
Meteorites like North Chile are low in nickel,  
lack Widmanstätten patterns and are called  
hexahedrites.



Earth.

**Youndegin meteorite**  
 Avon, Western Australia  
 Group IAB iron  
 First found in 1884.  
 Youndegin was the first meteorite  
 found in Western Australia.



## IRON METEORITES

Iron meteorites are much rarer than stones and are made of a nickel alloy commonly containing between 5-15% nickel. They have an internal structure of interlocking plates of metal. Many show a Widmanstätten pattern. The structure forms...



**Mount Edith meteorite**  
 Western Australia  
 Group IIIAB iron  
 This slice was taken from the 161 kilogram mass that was found in 1913 about 80 kilometres south-east of Onslow in the Ashburton district. The slice has been polished and acid treated to reveal the Widmanstätten pattern. Iron meteorites that show this structure are called octahedrites. The dark patches are nodules of the iron-sulphide mineral, troilite.

### INSIDE IRON METEORITES

Some irons show very fine Widmanstätten patterns, while others show very coarse patterns. These structures are a function of the cooling rate of the meteorites, and the rate at which they cooled depends on the size of the parent asteroids. From this, parent asteroids are estimated to be a few hundred kilometres in diameter. Some meteorites are separated from silicates during the formation of the iron core.

**Redfield's meteorite**  
 Wingen Hill, Victoria, Australia  
 Chemically, it is a nickel-iron alloy. It was recognized in 1869 by the Museum of Natural History in Copenhagen. The meteorite contains inclusions of the mineral...

**Iron River meteorite**  
 Iron River, Western Australia  
 Group IAB iron  
 First found in 1892 by G. Denmark.



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Group IIIAB iron

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### Bencubbin meteorite

Western Australia

Anomalous stony-iron  
related to the chondrites  
First found in July 1930.

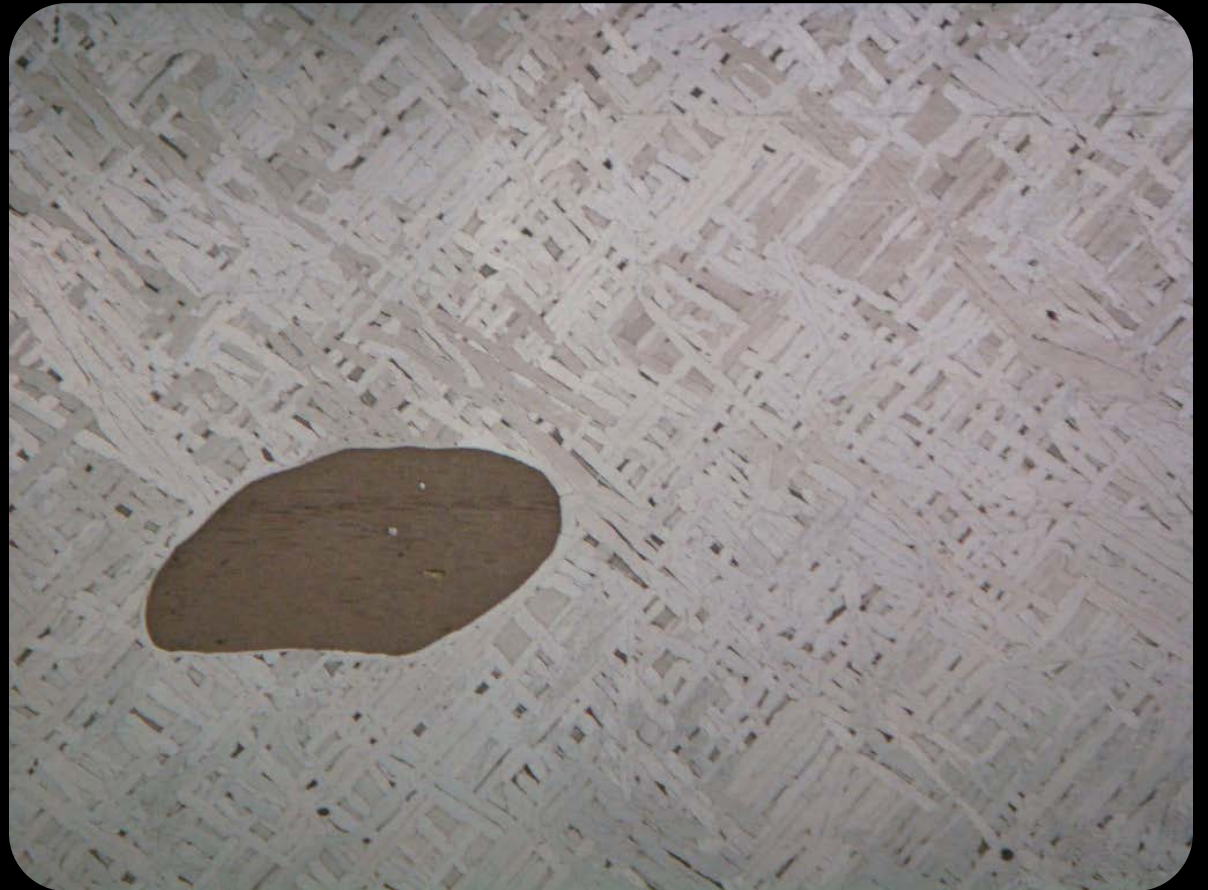


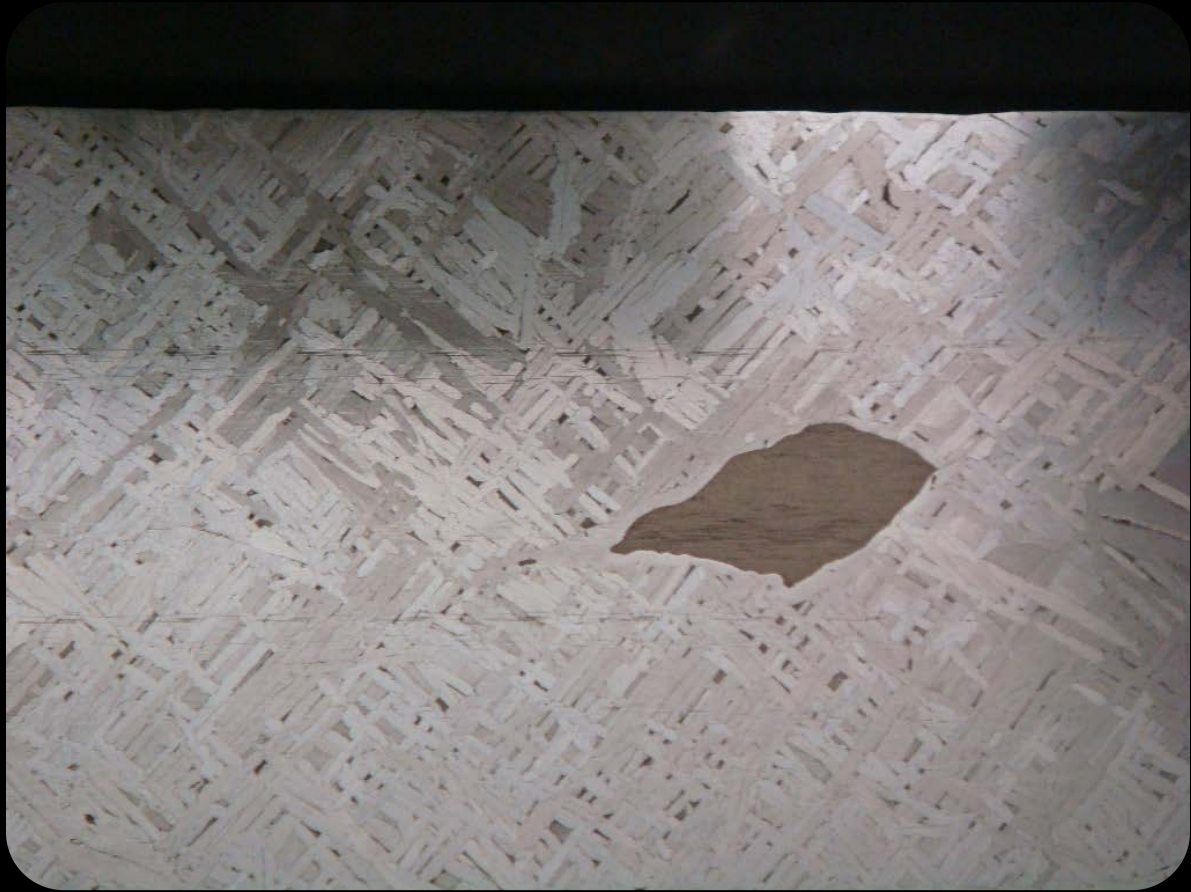


**Cape York meteorite**

Greenland  
Group IIIAB iron

Acid etched slice of the  
20 ton 'Agpalilik' mass of the  
Cape York meteorite showing  
the Widmanstätten pattern.



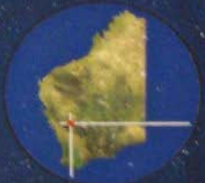




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produced by catastrophic collisions in space.



**Mount Magnet meteorite**  
Murchison Goldfield,  
Western Australia  
Chemically anomalous iron  
Found in 1916.  
Donated by J. Connors and H. Taylor.



## EROID rite

In 1966 near Mundrabilla  
Mr R. B. Wilson. The mass  
of the 11.5 tonne mass  
of this meteorite shower  
more than 70 km long on

Interior of an asteroid  
50 million years ago. Half  
acid to reveal the internal  
It is "iron forest" mixture  
interlocking plates of two  
serite, and the iron-

It was sent to the Mac-  
many where 12 slices  
and abrasive slurry,  
used up 30 wires, each 60  
abrasive. A further 10  
hand polish the slices.  
In museums throughout the  
Mundrabilla is the largest



**Millbillillie meteorite**  
Western Australia  
Eucrite achondrite  
Found by D. Vicenti  
Observed to fall in October  
1980 but not recovered until 1970, this  
meteorite, one of a large shower of stones,  
may be a fragment from the asteroid Vesta.



**Millbillillie meteorite**

*Western Australia*

Eucrite achondrite

Found by D. Vicenti.

Observed to fall in October 1960 but not recovered until 1970, this meteorite, one of a large shower of stones, may be a fragment from the asteroid Vesta.





# DEBRIS FROM THE ASTEROIDS

*Most meteorites formed 4 550 million years ago at the same time as the Earth but in a different region of the Solar System. Mainly representing some of the unaltered materials left over after the formation of the planets, meteorites carry important clues to the birth of the Solar System.*

Meteorites fall randomly over the Earth's surface. They fall in unpredictable numbers and sizes from photographs, sightings, or witness reports. In 1969, the first photograph of a meteorite fall was taken from a satellite in orbit. In 1970, a meteorite fell near the town of Chelyabinsk and was photographed by a satellite. The orbit of the meteorite was determined by a network of 100 satellites, and the meteorite was recovered. In 1972, a meteorite fell near the town of Chelyabinsk and was recovered. In 1972, a meteorite fell near the town of Chelyabinsk and was recovered. In 1972, a meteorite fell near the town of Chelyabinsk and was recovered.



The impact of a 1.2-ton meteorite near the town of Chelyabinsk on 15 March 1972 in China. The meteorite, which was the largest single stone meteorite ever seen, weighed 17.3 tonnes.



A specimen of a meteorite, showing the characteristic fusion crust and internal structure.

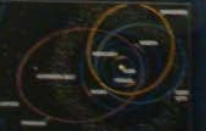


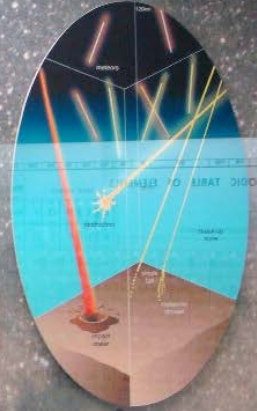
Diagram of the solar system, showing the orbits of the planets and the location of the asteroid belt.



Fragments of the Sikhotevinsk meteorite, which fell on 15 March 1972 in the Sikhotevinsk region of the USSR.

# FALLS & FINDS

*Each year the Earth sweeps up tens of thousands of tonnes of natural debris from space. Most of this arrives unseen as dust. Small fragments are destroyed in the upper atmosphere to appear as meteors. Larger fragments cause fireballs that give spectacular visual displays often associated with sounds. Most fragments are slowed by friction in the atmosphere to about 10-30 kilometres above the Earth's surface. Here fireballs extinguish and any remaining objects fall to Earth under gravity to become meteorites.*



The smallest meteoroids avoid frictional melting because their surface area, which is large compared to their mass, can quickly radiate heat. These particles pass through the atmosphere unchanged as cosmic dust. Other small meteoroids melt completely and the tiny beads that result fall to Earth as spherules. Interplanetary dust particles and cosmic spherules are known as micrometeorites.





The Binningup meteorite lying in the 1.5 cm pit in the sand where it fell.



### Binningup meteorite

Western Australia  
H-group ordinary  
chondrite (H5)



At 10:10 am on 30 September, 1985, this stony meteorite weighing 488.1 grams landed on Binningup beach (130 kilometres south of Perth) within 5 metres of two women sunbaking. Eight out of every ten meteorites seen to fall are 'stones' like Binningup.

### Camel Donga meteorite

Western Australia  
Eucrite achondrite

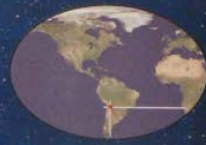


Many meteorites break up in the atmosphere to give rise to showers. These pieces of a single shower of more than a thousand fragments were found on the Nullarbor Plain since 1984. Their crusts show 'rivulets' of melted material that formed during high-speed flight through the atmosphere.





**Imilac meteorite**  
Atacama Desert, Chile  
Pallasite stony-iron  
Found before 1822.



**Vaca Muerta meteorite**  
*Taltal, Atacama, Chile*  
Mesosiderite stony-iron  
Found in 1861.



**Mount Padbury meteorite**  
*near Meekatharra, Western Australia*  
Mesosiderite stony-iron  
Found by W. C. Martin in 1964.

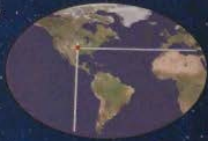


## MESOSIDERITES

These stony-irons are made of  
that are very similar to some

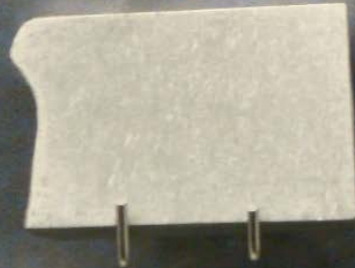


**Brenham meteorite**  
Kiowa County,  
Kansas, USA  
Pallasite stony-iron  
Found in 1882.



## PALLASITES

These mixtures of olivine crystals and iron-nickel metal are closely related to one chemical group of irons, group IIIAB. They may represent the region between the core and the outer stony part of its parent asteroid.



## Warburton Range meteorite

Western Australia  
Group IVB iron

Found in 1964 by H. Gill and G. Simms. The structures of iron meteorites like Warburton Range are not visible to the naked eye and are called ataxites, which is Greek for 'without structure'.

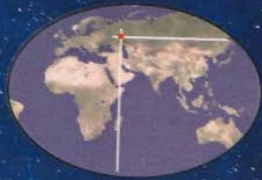


**Saratov meteorite**

*Russia*

L-group ordinary  
chondrite (L4)

Fell on 6 September,  
1918 at 3:00 pm.



eteorite shows shiny  
particles of iron-nickel  
metal.



**Barratta meteorite**

*Deniliquin,  
New South Wales*

L-group ordinary  
chondrite (L4)

Found in 1845, Barratta is one of the  
earliest meteorites discovered in Australia.



impacts.

**Bjurböle meteorite**  
 Finland  
 L-group ordinary  
 chondrite (L4)  
 Fell on 12 March, 1899  
 at 10:30 pm local time.




**CARBONACEOUS**  
 This rare group of meteorites



**Barratta meteorite**  
 Deniliquin,  
 New South Wales  
 L-group ordinary  
 chondrite (L4)  
 Found in 1845, Barratta is one of the  
 earliest meteorites discovered in Australia.




Fell on 20 December, 1845  
 at 2:00 pm but not recovered  
 by W. Hamlet and C. Monge

**ITES**  
 ites (C), are  
 compounds.  
 close to that

**Khairpur meteorite**

Pakistan

Enstatite chondrite  
Fell on 23 September,  
1873.



**Adelaide meteorite**

South Australia

Carbonaceous  
chondrite, anomalous  
Found in 1972.



Fell on 20 September, 1950 at 1:35 am  
Material similar to this meteorite may  
form the nucleus of a comet. Other forms  
of carbon have been found in carbonaceous  
meteorites including sub-microscopic  
diamonds that formed in the gas stream  
out from a star before our Solar System  
formed.

stony meteorites lack chondrules and contain very little, or no, iron.  
drites, and testify to melting of asteroids in the early Solar System.  
resemble volcanic rocks, or their debris, on both the Earth and  
n, while others chemically resemble metal-free chondrites.





1987.

### Murray meteorite

Callaway County,  
Kentucky, USA

CM2 carbonaceous  
chondrite



Fell on 20 September, 1950 at 1:35 am.  
Material similar to this meteorite may  
form the nucleus of a comet. Other forms  
of carbon have been found in carbonaceous  
meteorites including sub-microscopic  
diamonds that formed in the gas streaming  
out from a star before our Solar System  
formed.

eteorite



### Cook 003 meteorite

Nullarbor,  
South Australia

CK carbonaceous  
chondrite

Found by A. J. Carlisle in 1987.



### eteorite

y, Russia  
onaceous

September,  
5 pm.



### Adelaide meteorite

South Australia



### Murray m

Callaway Co  
Kentucky, US  
CM2 carbon  
chondrite

Fell on 20 Se  
Material simi  
form the nucl  
of carbon ha  
meteorites inc  
diamonds tha  
out from a ste  
formed.

Chondrite  
Found by A. J. Carlisle in 1987.

**Kainsaz meteorite**  
Muslyumov, Russia  
CO3 carbonaceous  
chondrite  
Fell on 13 September,  
1937 at 2:15 pm.



**Adelaide meteorite**  
South Australia  
Carbonaceous  
chondrite, anomalous  
Found in 1972.



**Lookout Hill meteorite**  
Nullarbor,  
Western Australia  
CM2 carbonaceous chondrite  
Found by A. J. Carlisle in 1974.  
Cast of original and cut piece.



**Kainsaz m**  
Muslyumov, R  
CO3 carbon  
chondrite  
Fell on 13 Sep  
1937 at 2:15

CHONDR  
WHEN ASTEROIDS  
These stony meteorites lack chondrules and cont

OBRRITES

silicate) and are closely related to the enstatite chondrites  
they may have been

ill meteorite

tralia

aceous chondrite

J. Carlisle in 1974.

al and cut piece.



AUBRITES

### Cumberland Falls meteorite

Whitley County,  
Kentucky, USA



Aubrite achondrite.

Fell on 9 April, 1919 at midday, local time.

The black patches are fragments of an  
unique type of chondrite that testify to  
mixing of some meteorite types during  
the early Solar System.

than  
rky pond.

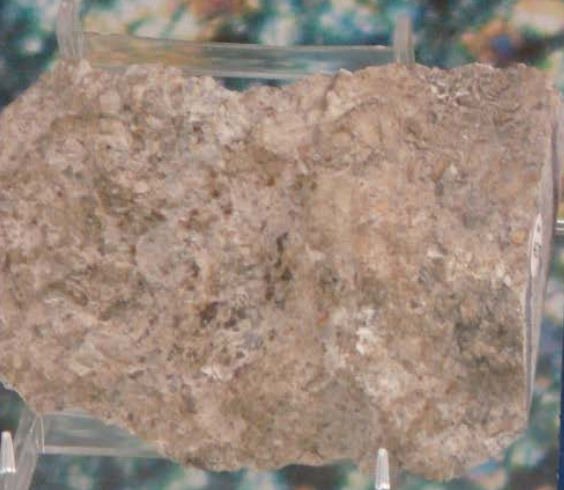


TES


Aubrite achondrite  
Fell on 9 April, 1919 at midday local time.  
The black patches are fragments of an  
unique type of chondrite that testify to  
mixing of some meteorite types during  
the early Solar System



and  
like



**Peña Blanca Spring meteorite**  
Brewster County,  
Texas, USA



Aubrite achondrite  
Fell on 2 August, 1946.  
A piece of a mass weighing more than  
60 kilograms that landed in a murky pond.

HOWARDITES, EUCRITES

A photograph of a rectangular, light-brown meteorite specimen with a porous, crystalline texture. It is mounted on a clear acrylic stand. To the right of the specimen is a dark blue informational card with white text and a small map of Texas. The background is a colorful, abstract pattern. Below the specimen, the text 'HOWARDITES, EUCRITES' is visible on a dark surface.



**Camel Donga meteorite**

Nullarbor,  
Western Australia

Eucrite achondrite  
First found in 1984  
by J. Campbell



**Juvinas meteorite**

Ardeche, France

Eucrite achondrite  
Fell on 15 June, 1821  
at 3:00 pm.



by impacts, and  
projectiles.



**Millbillillie meteorite**  
Western Australia  
Eucrite achondrite  
Fell in 1960,  
recovered in 1970.



**Millbillillie meteorite**  
*Western Australia*  
Eucrite achondrite  
Fell in 1960,  
recovered in 1970.





Dar al Gani 779 meteorite

*Sahara, Libya*

Howardite achondrite

Found in 1999

Howardites are cemented 'soils' from the surface of an asteroid. They contain fragments of other achondrites, such as eucrite and diogenite, and also rare fragments of chondrites that are almost always carbonaceous. Their textures show that they formed by the accumulation of broken fragments produced by impacts, and they contain pieces of both the target rocks and projectiles.





Dar al Gani 779 meteorite  
Sahara, Libya  
Howardite achondrite  
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### Johnstown meteorite

Weld County,  
Colorado, USA

Dioenite achondrite  
Fell on 6 July, 1924  
at 4:20 pm local time.

A cut slice from one of twenty-seven stones  
totalling 40.3 kilograms.



### Sardis meteorite

Burke County,  
Georgia, USA  
Group IAB iron

Found in 1940.

This meteorite is made  
of coarse interlocking crystals of the  
iron-nickel mineral kamacite and thin  
bands of the mineral taenite.





**Fragments of the Jilin meteorite**  
China  
H-group ordinary chondrite (H5)  
Fell on 8 March, 1976.  
Donated by the Chinese Academy of Sciences.



**Slice of the Sikhote-Alin meteorite**  
Russia  
Group IIAB iron  
Fell on 12 February, 1947.



*4 550 million years ago at the same time  
in a different region of the Solar System.  
some of the unaltered materials left over  
of the planets, meteorites carry imp  
the birth of the Solar Sys*

fall randomly over the Earth's surface. Their falls are  
rare and there are few photographic records. To determine  
where a meteorite has come from, photographs of its path must be  
taken at different locations at known times. In 1959, a meteorite  
fell in Czechoslovakia and was photographed by a network of cameras.  
The orbit of the meteorite and its entry velocity (about 15 km  
per hour) were calculated from the photographs. The meteorite  
falls at Lost City (USA) in 1970, and Innisfree (Canada) in 1983  
were also photographed. All three meteorites originated in  
the same region and travelled in elliptical orbits that brought them to Earth  
from the belt of asteroids between Mars and the giant planet, Jupiter.

A shower of meteorites totalling more than 23 tonnes fell on  
12 February, 1947 into the Sikhote-Alin mountains in the  
former USSR excavating 106 impact holes, the largest 28 metres  
across. This is the largest observed meteorite fall on record.

**Mulga (north) meteorite**  
Western Australia  
H-group ordinary  
chondrite (H6)

Weathered fragments of an ancient meteorite fall found in 1964 on the Nullarbor Plain. They were not seen to fall and so are called 'finds'. About 70% of all meteorites in collections throughout the world are finds. Dating tells us that this meteorite fell to Earth around 7 000 years ago.



**Mulga (north) meteorite**  
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# DEBRIS FROM THE ASTEROIDS

*Most meteorites formed 4 550 million years ago at the same time as the Earth but in a different region of the Solar System. Mainly representing some of the unaltered materials left over after the formation of the planets, meteorites carry important clues to the birth of the Solar System.*

Meteorites fall randomly over the Earth's surface. Their falls are unpredictable and have no photographic records. To determine where a meteorite has come from, photographs of its path must be taken from different locations at known times. In 1959, a meteorite fell near Pribram in Czechoslovakia and was photographed by a network of cameras. The path of the meteorite and its entry velocity (about 75 000 kilometres per hour) were calculated from the photographs. Two other meteorite falls at Los City (USA) in 1971, and Innisfree (Canada) in 1977, were also photographed. All three meteorites originated in the Solar System and travelled in elliptical orbits that brought them to Earth from the belt of asteroids between Mars and the giant planet, Jupiter.

The impact hole of a 1777 meteorite (see also slide shown that fell on 8 March 1992 in Glenelg). The meteorite, which is the largest single stone known, was later recovered from a depth of 4 metres.

Fragments of the 1992 meteorite  
Glenelg  
A group ordinary chondrite with  
Fall on 8 March, 1992.  
Recovered by the Glenelg School of Science.

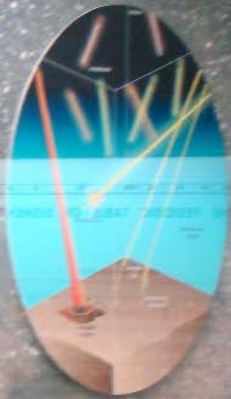
THE PERIODIC TABLE OF ELEMENTS

of meteorites weighing more than 23 tonnes fell on 1928 February, 1947 was the Sikhotealin meteorite in the USSR measuring 100-metre diameter, the largest 20 metres is the largest observed meteorite fall on record.

Known: Los City and Innisfree meteorites. All used in human space and higher occupied by small size solar systems.

# FALLS & FINDS

As the Earth sweeps up tens of thousands of tonnes of natural space debris each day, most of this arrives unseen as dust. Small fragments are seen in the upper atmosphere to appear as meteors. Larger fragments are seen as fireballs that give spectacular visual displays often associated with meteor showers. Most fragments are slowed by friction in the atmosphere to about 100 metres above the Earth's surface. Here fireballs, cosmic and other objects fall to Earth under gravity to become meteorites.



The smaller meteoroids avoid frictional heating because their surface area, which is large compared to their mass, can quickly radiate heat. Larger particles pass through the atmosphere unchanged as cosmic dust. Other small meteoroids melt completely and the lava droplets that result fall to Earth as spherules. Impassioned dust particles and cosmic spherules are known as micrometeorites.



# METEORITE DIVERSITY

## CHONDRITES

Chondrites are primitive meteorites that contain small, rounded grains called chondrules. They are the most abundant type of meteorite and are found in all meteorite collections. They are named after the Greek word 'chondros', meaning 'pebble'.



## PALLASITES

Pallasites are a type of meteorite that contain large, rounded grains of olivine crystals surrounded by a matrix of iron-nickel metal. They are named after the Russian astronomer Heinrich Olbers.



## MESOSIDERITES

Mesosiderites are a type of meteorite that contain a mixture of iron-nickel metal and silicate minerals. They are named after the Greek word 'mesos', meaning 'middle'.

There are three main kinds of meteorite - stones, irons, and stony-irons - although this simple grouping conceals the diversity of meteorites that fall to Earth.

## IRON METEORITES

Iron meteorites are a type of meteorite that are composed almost entirely of iron-nickel metal. They are the most common type of meteorite found on Earth.



## STONY METEORITES

Stony meteorites are a type of meteorite that are composed primarily of silicate minerals. They are the most common type of meteorite found on Earth.






**Dar al Gani 400 meteorite**  
Sahara, Libya  
Lunar achondrite (a fragment of the Moon)  
Found in 1998  
A complex mixture of rock fragments, this meteorite is typical of the highlands of the Moon. An impact blasted the rock from the Moon around 1-3 million years ago, and it fell to Earth in the Libyan Sahara.




**Nakhla meteorite**  
Egypt  
Martian achondrite  
Fragment from a shower of stony meteorites that fell in Egypt in 1911, one of which is reported to have killed a dog. This igneous rock from Mars, which formed 1 300 million years ago, is much younger than most other meteorites (4 560 million years) and so must have come from a large parent planet with active volcanoes at that time.



**Reid 011 meteorite**  
Nullarbor, Western Australia  
H-group ordinary chondrite  
(H3-6)  
Found in 1986 by C. Bradly.



**Reid 011 meteorite**  
Nullarbor, Western Australia  
H-group ordinary chondrite  
(H3-6)  
Found in 1986 by C. Bradly.







teorite  
tern Australia  
ary chondrite  
by C. Bradly.



**Kybo 001 meteorite**  
Nullarbor, Western Australia  
LL-group ordinary chondrite  
(LL5)  
Found in 1984 by J. Campbell.

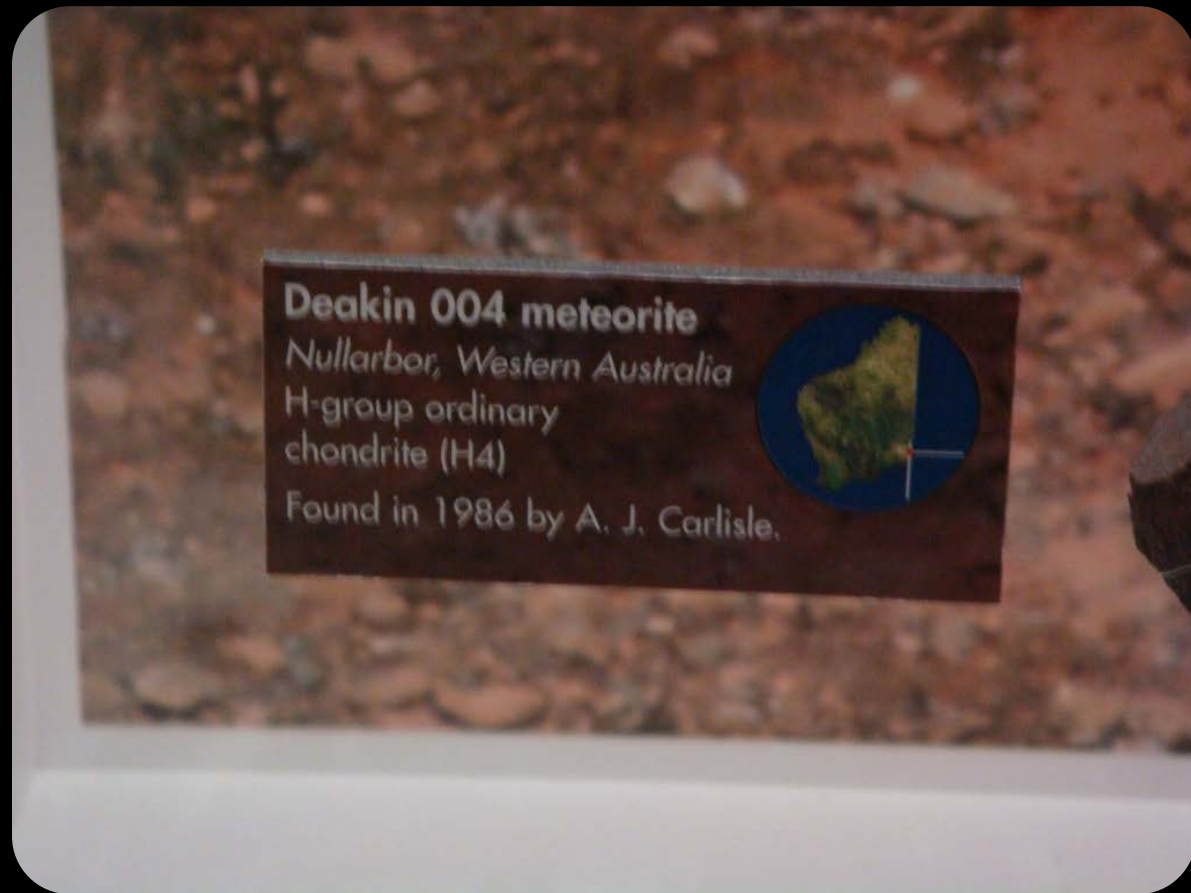
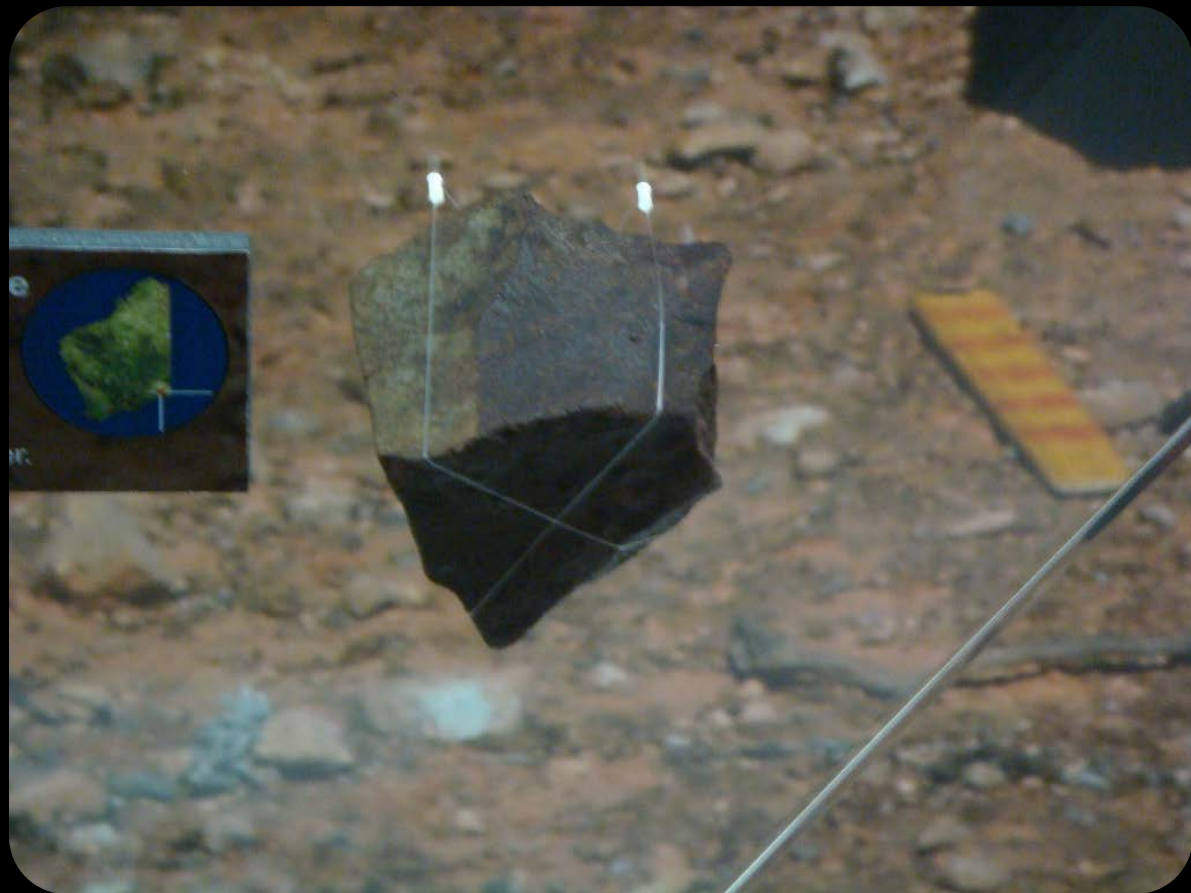
**Kybo 001 meteorite**

*Nullarbor, Western Australia*  
LL-group ordinary chondrite  
(LL5)



Found in 1984 by J. Campbell.





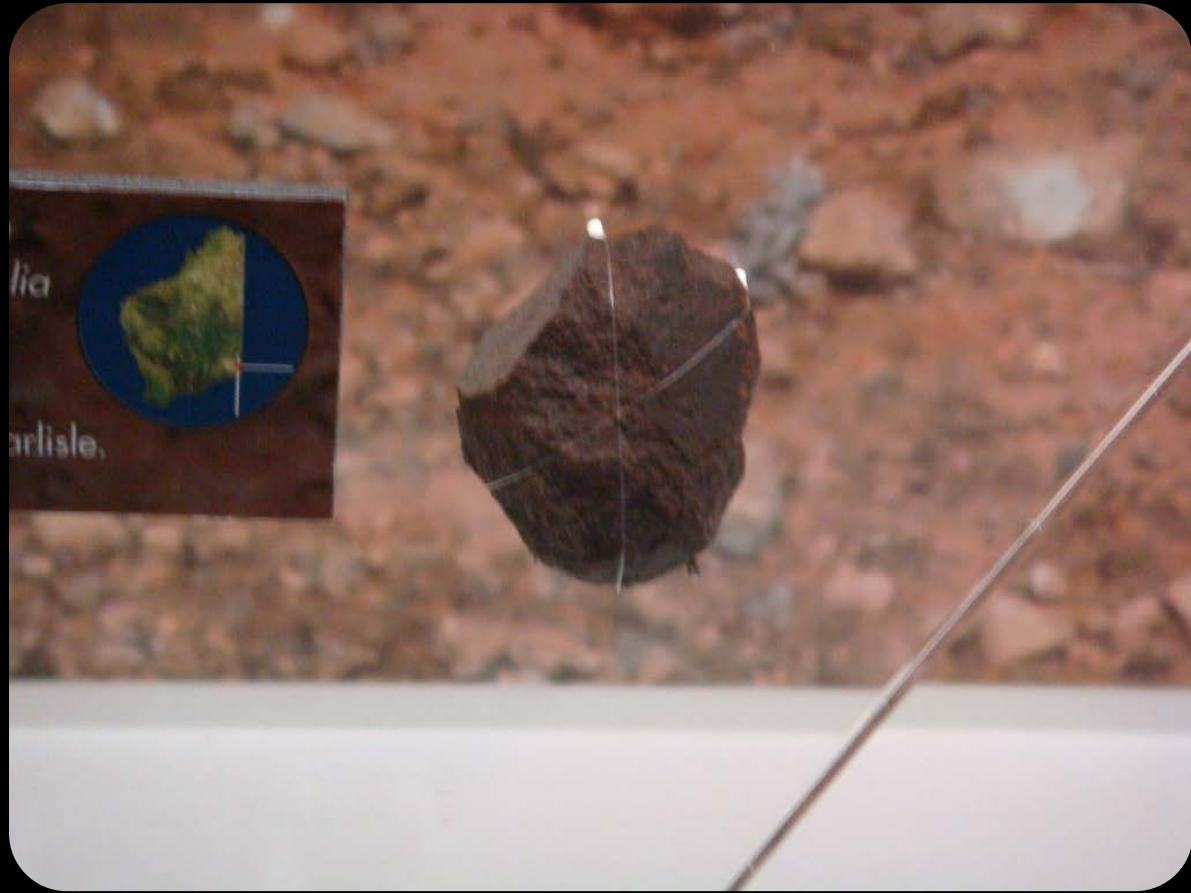
**Deakin 004 meteorite**

*Nullarbor, Western Australia*

H-group ordinary  
chondrite (H4)

Found in 1986 by A. J. Carlisle.





**Allan Hills 76009  
meteorite**

*Antarctica*

L-group ordinary chondrite  
(L6)



This slice is part of masses totalling 407 kilograms found in 1976 on the Allan Hills icefield in Antarctica. Sometimes trapped in the ice for more than a million years, meteorites have been found in many parts of Antarctica.



09



chondrite



**Allan Hills 76009  
meteorite**

*Antarctica*

L-group ordinary chondrite  
(L6)



This slice is part of masses totalling 407 kilograms found in 1976 on the Allan Hills icefield in Antarctica. Sometimes trapped in the ice for more than a million years, meteorites have been found in many parts of Antarctica.



## METEORITES FROM THE ICE

Since 1969, tens of thousands of fragments of an unknown number of different meteorites have been found in Antarctica. Meteorites are generally found in 'blue ice' areas where fierce winds have stripped the ice from the surface. Meteorites that fell in the distant past and became preserved in the ice are now being concentrated on erosion surfaces.



*Meteorite falls are rare and unpredictable, so scientists also study meteorite finds. Until 1969 there were only 2 100 meteorites known to science. Since the discovery of nine fragments of four different meteorites on ice at Yamato in Antarctica, and the realisation that meteorites are preserved in deserts for thousands of years, the numbers in collections have more than doubled.*

## METEORITES ON THE NULLARBOR

Many meteorites are found in deserts where low rainfall allows their preservation. Several thousand specimens of more than 500 different meteorites are currently known from Australia, with more than 50% found in the Nullarbor Region. Straddling the border between Western and South Australia, the Nullarbor has remained dry and stable for tens of thousands of years, which has allowed meteorites to accumulate. Pale limestone and a general lack of vegetation allows for easy recognition of dark meteorites. Several other parts of the world, notably Roosevelt County in New Mexico, USA, and the deserts of south Africa and Chile.





**Bunjil meteorite**  
*near Latham, Western Australia*  
L-group ordinary chondrite (L6)  
Found by P. Just in 1971.

## Bunjil meteorite

*near Latham, Western Australia*

L-group ordinary chondrite (L6)

Found by P. Just in 1971.





**Bunjil meteorite**  
near Latham, Western  
L-group ordinary  
Fe-Ni







**Mies meteorite**  
Queensland  
Group II E iron  
Found in 1991.  
Main mass. Mies contains some silicates and may have  
come from the asteroid Hebe.






**Mount Padbury meteorite**  
*near Meekatharra, Western Australia*  
Mesosiderite  
Found by W. C. Martin in 1964.



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Allende has  
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**Allende meteorite**  
Mexico  
CV3 carbonaceous  
chondrite



Fell on 8 February, 1969 at 1:05 am.  
More than two tonnes of stones fell over  
an area of 150 square kilometres near the  
town of Pueblito de Allende. Allende has  
allowed scientists to unravel much of the  
earliest history of the Solar System. The  
large white inclusions made of high  
temperature minerals were among the first  
materials to form in the Solar System 4 566  
 $\pm$  2 million years ago. Allende also contains  
tiny diamonds, and grains of the minerals  
silicon carbide and corundum. The  
diamonds formed in the atmospheres of  
red giant stars, or in supernova explosions  
that predate the Solar System. This debris  
seeded the collapsing 'solar cloud' and  
became mixed with the condensing material.



**Gundaring meteorite**

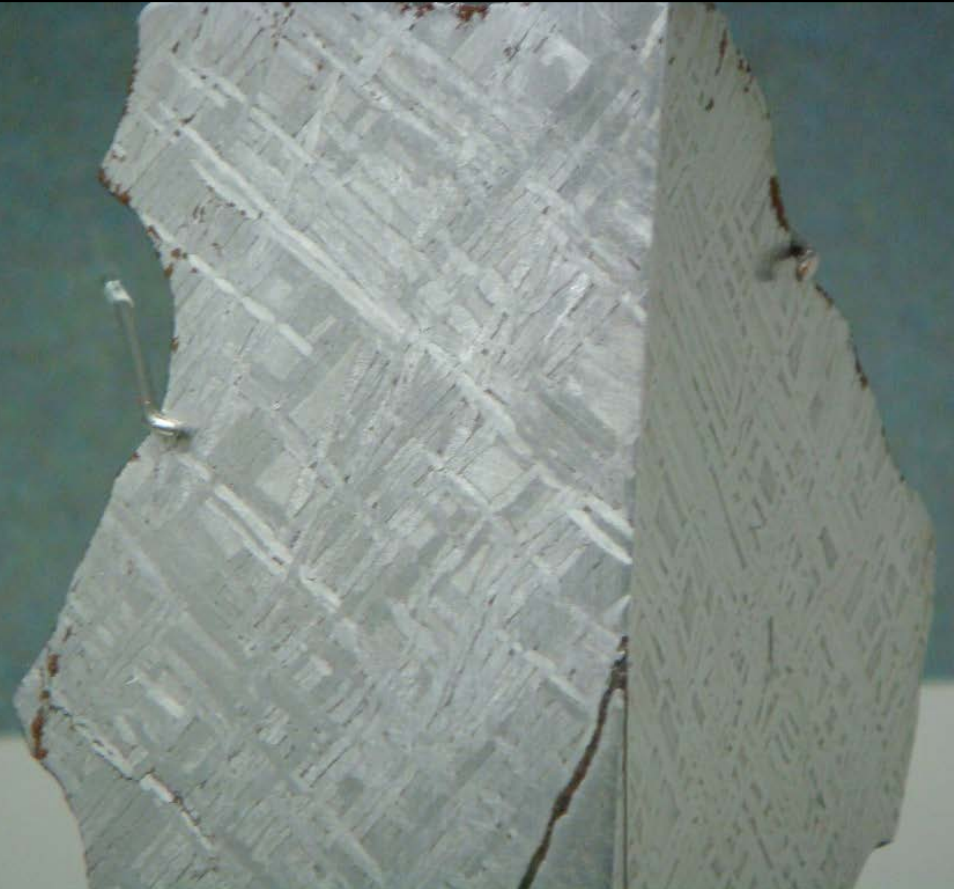
*Western Australia*

Group IIIAB iron



Found by F. Quinn in 1937.

Radioactive isotopes of potassium indicate that this meteorite spent around 700 million years as a small object in space before landing on Earth.



### **Burnabbie meteorite**

*Nullarbor Region,  
Western Australia*

H-group ordinary chondrite  
(H5)



Found by A. J. Carlisle (Jr) in 1965.  
Measurement of the radioactive carbon-14  
with a half-life of 5 730 years in this  
meteorite shows that it landed on Earth  
around 28 000 years ago.



### **Barwell meteorite**

*Leicestershire,  
England, UK*

L-group ordinary  
chondrite (L6)



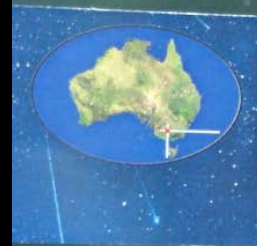
Fell on Christmas Eve, 1965 at 4:20 pm.  
Measurement of the isotopes of uranium  
and lead in meteorites like this tell us that  
it formed as a solid rock around 4 560  
million years ago. Although it formed in  
another part of the Solar System we take  
this age as the upper limit of the age  
of the Earth.



formed near  
asteroids.



**Kumerina meteorite**  
Near Batewmurnana Hill,  
Western Australia  
Group IIC iron  
Found by J. Merrick in 1937.



**Estherville meteorite**  
Emmet County,  
Iowa, USA  
Mesosiderite stony-iron  
Fell on 10 May, 1879  
at 5:00 pm  
Meteorites like this probably formed near  
the surfaces of small melted asteroids.



Kumer



**Henbury meteorite**  
Northern Territory,  
Group IIIAB iron  
Found in 1933.



D THAT MELTED



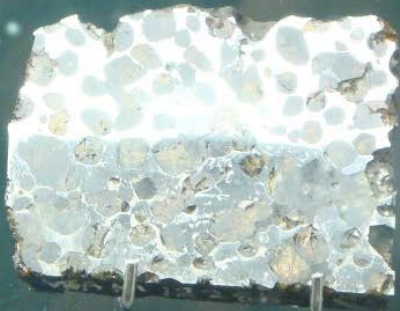
**Springwater meteorite**  
Saskatchewan,  
Canada  
Pallasite stony-iron  
Found in 1931.



**Moama**  
Wombour  
New South  
Euclite ach  
Found in 1  
a few mont

**Millbillillie meteorite**  
Western Australia  
Euclite achondrite  
Fell in 1960,  
recovered in 1970.





**Springwater meteorite**

Saskatchewan,  
Canada

Pallasite stony-iron

Found in 1931.



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**Miles meteorite**

Queensland  
Group II E iron

Found in 1991.

Miles contains some silicates and may have  
come from the asteroid Hebe.





**Jeedamyia meteorite**

*Western Australia*

H-group ordinary  
chondrite (H4)

Found by R. Blizzard in 1971.



**Wiluna meteorite**

*Western Australia*

H-group ordinary  
chondrite (H5)

Fell on 2 September,  
1967 at 10:46 pm.



**Julesburg meteorite**

*Sedgewick County,  
Colorado, USA*

L-group ordinary  
chondrite (L3)

Found in 1983.



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atite chondrites  
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**Plainview (1917)  
meteorite**

*Hale County,  
Texas, USA*  
H-group ordinary  
chondrite (H5)  
Found in 1917.



**Atlanta meteorite**

*Louisiana, USA*  
Enstatite chondrite  
Found in 1938.





# ORIGIN OF THE EARTH & PLANETS

**FRICES OF THE SUN**  
The Sun is a ball of hot gases, mostly hydrogen and helium, that has been burning for billions of years. The heat and light from the Sun are what make life possible on Earth.

*Although it is not known exactly how the planets were built, scientists know some of the events that led to the fiery birth of the Sun and its system of planets. It is now known that the growth of planets and asteroids and, for a time, their subsequent melting happened within a time interval between about 4,570-4,550 million years ago.*

**THE ASTEROIDS**  
Asteroids are rocky objects that orbit the Sun. They are the remnants of the protoplanets that formed in the early stages of the solar system.

**ANATOMY OF THE ASTEROIDS**  
Asteroids are made of different materials, including rocks, metals, and ice. Some are very dark, while others are very bright.

**IMPACTING THE MEXICAN PENINSULA**  
A large asteroid struck the Earth in the Yucatan Peninsula, creating the Chicxulub crater. This event is believed to have caused the extinction of the dinosaurs.

**HOW OLD IS CRYSTAL**  
The oldest known crystal is a zircon crystal from Australia, which is about 4,400 million years old.

**4,000 M**

# SEARCHING FOR THE PAST

*Meteorite falls are rare and unpredictable, so scientists also study meteorite finds. Until 1969 there were only 2,100 meteorites known to science. Since the discovery of nine fragments of four different meteorites on ice at Yamato in Antarctica, and the realization that meteorites are preserved in deserts for thousands of years, the numbers in collections have more than doubled.*

**METEORITES FROM DESERTS**

**METEORITES ON THE HIGHLANDS**

**METEORITES FROM THE ICE**

# MARS

## THE BOMBARDED EARTH

### BLASTS FROM THE PAST

Throughout the Earth's history, its surface has been bombarded by large comets and asteroids. Over 150 impact craters and basins are scattered across the Earth's surface, ranging from one of meters in depth to 1000 kilometers in diameter, and from a few thousand years to more than 2 billion years old. Some are easily recognized as bowl-shaped craters, which have steeply eroded and only appear as slightly circular hollows in the Earth's surface rocks. Some, like the one in the foreground, are the remains of impact craters that have been partially filled by lava flows.



### FROM THE MOON

We have gained much detailed information about the Moon from rocks returned to Earth by several Apollo, Luna, and Chang'e lunar missions and by lunar orbiters. In addition, billions of meteorites, lunar breccias, and rock fragments have been found on Earth. Some of these rocks are thought to be fragments of the Moon that were ejected during the impact events that formed the Moon.

# MOON & MARS

## ROCKS FROM THE MOON AND MARS

Since 1969 we have gained much detailed information about the Moon from rocks returned to Earth by manned Apollo space missions launched by the United States National Aeronautics and Space Administration (NASA) Space program. In addition, thousands of meteorites, many of which are thought to have come from the Moon, have been found in Algeria, and some have been found in Western Australia and near the Sahara in Algeria. The importance of lunar meteorites is that they come from areas of the Moon not sampled by manned missions. Another fourteen meteorite specimens are known to be pieces of the planet Mars.



### ASTS FROM

# THE BUILDING BLOCKS OF PLANETS

## METEORITE DIVERSITY

There are three main kinds of meteorite - stony, iron, and stony-iron - although this roughly grouping conceals the diversity of meteorites that fall to Earth.



## DEBRIS FROM THE ASTEROIDS

Most meteorites formed 4.560 billion years ago at the same time as the Earth but in a different region of the Solar System. Mainly representing some of the unaltered materials left over after the formation of the planets, meteorites carry important clues to the birth of the Solar System.









**Haig meteorite**  
**Nullarbor, Western Australia**  
**Group IIIAB iron**

A mass of 450 kilograms found in 1951 in the Nullarbor south of Rawlinna on the Trans Australian Railway. Presented by the finders, A. J. and H. E. Carlisle. The thumb print like depressions on the surface of the meteorite, called regmaglypts, resulted from turbulent airflow and uneven melting when it passed through the atmosphere.





4th in the Ashburton district  
165.1 kilograms when  
found



**Mount Edith meteorite**  
**Western Australia**  
**Group IIIAB iron**  
The second of two large masses found in the Ashburton district  
in 1913-14. This larger mass weighed 165.1 kilograms when  
it was found by James Bourke in 1914.



**Youanmi meteorite**

*Western Australia*

**Group IIIAB iron**

A mass of 118.5 kilograms was found in 1917  
about 80 kilometres south of Youanmi.





**Dar al Gani 476 meteorite**  
Sahara, Libya  
Martian achondrite  
Found in 1998  
Many meteorites that probably  
came from Mars are now being found preserved in  
the world's deserts.





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**Nakhla meteorite**

*Egypt*  
Martian achondrite



Fragment from a shower of stony meteorites that fell in 1911, one of which is reported to have killed a dog. This igneous rock from Mars, which formed 1 300 million years ago, is much younger than most other meteorites (4 560 million years) and so must have come from a large parent planet with active volcanoes at that time.



**Zagami meteorite**

*Nigeria*  
Martian achondrite



A slice of the meteorite originally weighing 88 kilograms that fell on 3 October, 1962. Like Nakhla it has proved to be from Mars. NASA's Mars missions have included the two Viking unmanned probes that were launched in 1975 and 1976. The probes analysed soil and atmosphere samples and relayed the results to Earth. The composition of the Martian atmosphere is a close match for the gases contained in these meteorites and provide part of the proof that they came from Mars.



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# THE ORIGIN OF LIFE?



*In the Murchison meteorite, the discovery of amino acids and many other complex carbon compounds of non-biological origin that formed more than 4 550 million years ago in the Solar System has revolutionised our views of how life on Earth might have evolved.*

*Amino acids are the basic ingredients of proteins which are, in turn, the building blocks of cellular organisms. While the complex materials found in meteorites such as Murchison cannot be interpreted as 'life', they represent some of the essential ingredients from which simple organisms might have been constructed on the surface of the early Earth.*

*Meteorites like Murchison may represent the original materials from which the Earth gained water for its oceans, gases for the atmosphere we breathe, and the essential ingredients for the origin of life.*

**Murchison meteorite**  
Victoria, Australia  
CM2 carbonaceous chondrite

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**Murchison meteorite**  
Victoria, Australia  
CM2 carbonaceous chondrite

One of over 100 kilograms of stones that fell around 10:45 am on 28 September, 1969. It contains abundant complex carbon compounds and water from space. The carbon compounds were formed by chemical reactions and not by living organisms. Material similar to Murchison may form the nucleus of a comet. Other forms of carbon have also been found in meteorites like Murchison including sub-microscopic diamonds and silicon carbide.



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## IRON METEORITES

These two meteorites were found by Mr A.J. Carlisle in the Nullarbor Plain north of Mundrabilla siding and about 630 km east of Kalgoorlie.

Weighing about 840 kg and 800 kg, the meteorites are similar to the 11-tonne Mundrabilla iron meteorite on display in the Francis Street foyer of the Museum.



